I. "On a certain Excretion of Carbonic Acid by Living Plants." By J. Broughton, B.Sc., F.C.S., Chemist to the Cinchona Plantations of the Madras Government. Communicated by J. D. Hooker, M.D., F.R.S. Received March 31, 1869.

[Abstract.]

While the author was engaged in some experimental determinations of the changes that take place in the composition of the Cinchona barks after being taken from the tree, he noticed a somewhat singular circumstance, which induced him to institute a series of experiments, by which he discovered that the various parts of living plants excrete carbonic acid, not only in their normal condition, but after they have been deprived for days together of all access of oxygen. The experiments were mostly made on cut portions of the plants; but experiments were also made, for control, on plants as they actually grow. The deprivation of oxygen was effected sometimes by Sprengel's air-pump, sometimes by substituting for air an atmosphere of hydrogen or nitrogen; while comparative experiments were made on plants supplied with air that had been freed from carbonic acid. The main conclusions to which he was led are those enunciated by the author: —

1st. That nearly all parts of growing plants evolve carbonic acid in considerable quantities, quite independently of direct oxidation.

2nd. That this evolution is connected with the life of the plant.

3rd. That it is due to two causes, namely, to previous oxidation, resulting after a lapse of time in the production of carbonic acid, and to the separation of carbonic acid from the proximate principles of the plant while undergoing the chemical changes incident to plant-growth.

II. "On the Causes of the Loss of the Iron-built Sailing-ship 'Glenorchy.'" By Archibald Smith, Esq., M.A., LL.D., F.R.S. Received April 15, 1869.

When the loss of an iron-built vessel has been caused by an error in the direction of her course by dead reckoning, as derived from her course by compass, it is a question of scientific interest whether the error has or has not arisen from an error in the assumed deviation of the compass. By careful consideration of all the circumstances of the case, and by piecing together the generally scanty fragments of information which can be obtained as to the magnetic state of the ship, a probable or certain answer to this question may be given more frequently than might be supposed possible by those who do not know how perfectly definite and well ascertained the laws of the deviation of the compass are, how small is the number of quantities involved which are peculiar to each particular ship, and from what apparently slight indications an approximate estimate of the numerical values of these quantities can be made.

The case the circumstances of which I now propose to lay before the Royal Society, is one in which it appears to me that a positive answer to the question can be given. It will, I hope, be found to have some interest as an example of the manner in which such an answer can be elicited from the data. It may have some scientific interest as the first case in which any information as to the magnetic character of an English merchant-ship has been published since the publication of the Third Report of the Liverpool Compass Committee in 1861; and I think it will be found to have much practical interest, as bringing into prominence a particular error of great importance, not as yet, I believe, ascertained or corrected in the usual course of adjustment of compasses in merchant-ships, even by the most experienced and skilful compass-adjusters, but which, ever since the mode of ascertaining and correcting it without heeling the ship was given in the 'Admiralty Manual for the Deviation of the Compass' in 1862, has been ascertained, and when necessary corrected, in the ships of the Royal Navy, viz. the Heeling Error. The case to which I refer is the loss of the ship 'Glenorchy' of Glasgow, on the Kish Bank, in Dublin Bay, on the 1st of January 1869, on which a court of inquiry was held under the direction of the Board of Trade in pursuance of the Merchant Shipping Act. In examining this case I have had the advantage, by the permission of the Board of Trade, of perusing the evidence taken before the Court of inquiry, and the report of the Court. I have also had the advantage of discussing the nautical as well as the magnetical circumstances of the case with Captain Evans, F.R.S., the highest authority in all that relates to such an inquiry, and who permits me to state his concurrence in the conclusions at which I have arrived; and above all, I have to express my obligations to Mr. William Fleming, compass-adjuster, James Watt Street, Glasgow, for the full particulars with which he has kindly furnished me of the deviations and correction of the compasses of the 'Glenorchy'—information without which the results of this inquiry would have been in a great measure conjectural.

The 'Glenorchy' was an iron-built sailing-ship of 1200 tons, having an iron poop, with a wooden deck laid upon iron beams, with iron bulwarks, except on the poop-deck, above which there was a light rail. She was built at Dumbarton in 1868. Her head in building was about N.N.E. After being launched she was taken to Glasgow, where she lay for some time head N.W. taking in a cargo of about 1100 tons of iron railway-chairs and sleepers.

She had two compasses on deck—a steering-compass and a standard compass. The card of each had two edge-bar needles $8\frac{3}{4}$ inches long, the ends separated 50°.

The steering-compass was near the stern, about 32 or 33 inches above the poop-deck, and 2 feet in front of the steering-wheel, which had an iron spindle. The standard compass was on a wooden pillar about 5 feet high,

standing on a wooden platform laid from the poop to the mainmast, and about 15 feet abaft the mainmast, which was of iron.

On the 18th of December the 'Glenorchy' had her compasses adjusted in the Gareloch by Mr. Fleming in the usual way.

The deviation of the steering-compass, as might have been expected from the combined effect of the position of the compass in the ship and of the ship in building, was *enormous*. Mr. Fleming says it was "as bad if not worse than any he ever saw." Mr. Fleming informs me that before magnets were applied to the steering-compass, when the ship's head bore N. (magnetic) it bore S. by the steering-compass; when the ship's head bore W. (magnetic) it bore about S.W. by S. by the steering-compass. In other words, at N. (magnetic) there was a deviation 180°, at W. (magnetic) a deviation of about 56° 15′ E. The quadrantal deviation was about 10°.

These data give, using the notation of the 'Admiralty Manual for the Deviation of the Compass,'

$$\mathfrak{B} = -1{\cdot}250,$$
$$\mathfrak{C} = \quad 0,$$

or a force of the ship to the stern exceeding by one-fourth the whole directive force of the earth's magnetism acting on the compass, a disturbing force about twice as great as that found at the steering-compass in any of the iron-built armour-plated ships in Her Majesty's Navy.

This enormous disturbing force was corrected by three large magnets one of 36 inches and two of 26 and 28 inches placed together, fore and aft, on the starboard side of the binnacle, and by two or three smaller magnets placed so as to correct as far as possible the residual error on the other cardinal points.

The ship was then placed head N.W. (magnetic), when a westerly deviation of three-fourths of a point 8° 26′ was observed. This was of course approximately the amount of the quadrantal deviation, and it was corrected by a No. 12 iron jack-chain placed in the chain-boxes on each side of the compass.

The ship was then swung on sixteen points and the following deviations of the steering-compass obtained (+ signifying that the N. point of the needle was drawn to the E., − to the W.).

'Glenorchy' Steering-Compass, December 18, 1868.

Magnetic Course.	Deviation.	Magnetic Course.	Deviation.
N.	0	S.	−2°
N.N.E.	+3°	S.S.W.	+3
N.E.	+7	S.W.	0
E.N.E.	+2	W.S.W.	0
E.	+3	W.	+5
E.S.E.	−3	W.N.W.	−3
S.E.	−2	N.W.	0
S.S.E.	−1	N.N.W.	−2

From these I derive the following expression for the deviation (δ) in terms of the azimuth of the ship's head (ζ) measured eastward from the magnetic N.

$$\delta = 30' + 30' \sin\zeta + 1^\circ\ 2' \cos\zeta + 2^\circ\ 37' \sin 2\zeta - 38' \cos 2\zeta.$$

These values show that the semicircular deviation had been entirely corrected. Of the quadrantal deviation a small part appears to have been uncorrected. There are practical difficulties in the way of correcting very large amounts of this deviation by soft iron, and I have no doubt Mr. Fleming acted with judgment in not attempting to carry this correction further. We may probably assume the maximum quadrantal deviation to have been about 10°.

The standard compass was not corrected by magnets, but its deviations were observed, and a Table of the deviations furnished. They were:—

'Glenorchy' Standard Compass, December 18, 1868.

Magnetic Course.	Deviation.	Magnetic Course.	Deviation.
N.	+12°	S.	− 5°
N.N.E.	− 7 30′	S.S.W.	+ 7 30′
N.E.	−24	S.W.	+16
E.N.E.	−37 30	W.S.W.	+22 30
E.	−38	W.	+33
E.S.E.	−31 30	W.N.W.	+35 30
S.E.	−24	N.W.	+35
S.S.E.	−11 30	N.N.W.	+20 30

These values give

$$\mathfrak{A}=0,\quad \mathfrak{B}=-\cdot610,\quad \mathfrak{C}=+\cdot105,\quad \mathfrak{D}=+\cdot100,\quad \mathfrak{E}=0.$$

This Table and these values do not bear directly on the loss of the ship, because owing, as I collect, to the unsteadiness of the pillar the standard compass was found to be useless, and the ship was navigated by the steering-compass alone; but it is interesting from the light it throws on the general magnetic character of the ship, and its confirmation of the results obtained from the steering-compass.

The proportion of $\mathfrak{C}$ to $-\mathfrak{B}$ exactly agrees with what we know of the direction in which the ship was built.

The large value of $-\mathfrak{B}$ was no doubt owing to the original magnetism of the hull and not to the iron cargo, which in fact probably rather diminished than increased the $-\mathfrak{B}$.

Cards containing the deviations of both compasses were furnished to the captain.

The question of the correction of the standard compass by magnets is one which has become of so much importance that I may be pardoned for interposing a digression on this subject and for inserting a passage from the third edition of the 'Admiralty Manual' now in the press.

"The question of the mechanical deviation of the compass has materially changed its aspect of late years. Before that time the deviation of a properly placed standard compass was of moderate amount, its maximum seldom exceeding 20°, and the directive force which acted upon it being generally comprised within the limits of two-thirds and four-thirds of the mean force. There was then no difficulty and some advantage in dispensing altogether with mechanical correction; or, if mechanical correction was employed, it was possible, at least in vessels which did not change their magnetic latitude, to make the correction so complete that tabular correction might be dispensed with. But in the present day it is frequently impossible to find a position for the standard compass at which the deviation and the variation of directive force do not greatly exceed these limits. In such cases the application of magnets for the purpose of equalizing the directive force on different azimuths becomes a matter of necessity; while at the same time the danger of trusting to mechanical correction alone without ascertaining and applying the residual errors is increased.

"This change of the condition of the question has produced a corresponding change in the practice in the Royal Navy.

"The same care as before is still used in the selection of a place for the standard compass; but a magnet is frequently or generally introduced for the purpose of equalizing the directive force on different azimuths, and at the same time diminishing the semicircular deviation. The quadrantal deviation is not often corrected mechanically, but is generally left for tabular correction.

"The heeling deviation is always ascertained, and is sometimes corrected mechanically."

After the 'Glenorchy' was swung she took in an additional quantity (about 120 tons) of iron. I do not, however, think it possible that this quantity could have altered the deviations sensibly.

The 'Glenorchy' sailed from Greenock on the 25th of December. She had on board a pilot accustomed to the navigation of the Irish Channel. She was towed to Lamlash Harbour, in the Island of Arran, where she lay till 3 A.M. on the 31st of December. She then got under way, the wind blowing moderately from the N.W., and steered a course down mid-channel, sighting the Copeland, the Mull of Galloway, the North and South Rock, St. John's Point, and the Calf of Man lights.

The wind gradually heading her, she tacked about 6.15 A.M. on the 1st of January. At 7.10 A.M. her position was determined by a bearing and distance of the South Stack Light, which then bore S. by W., distant five miles.

Till the ship tacked she had been on the starboard tack, on courses from S.W. to S., on which the deviation-card gave small deviations for the steering-compass. The bearing of the lights successively passed had,

however, been carefully taken by the captain, and from these he found that the compass had a westerly deviation of one point not shown by the deviation-card. From 7.10 A.M. till 3 P.M. the ship was on the port tack, sailing by the wind but kept good full, her course by the steering-compass being about S.W. by W. During the whole of this time a gale of wind was blowing from S.S.E., gradually increasing in intensity, with thick weather and rain, which cleared only for a little about 1.30, when land was seen in the distance bearing W.N.W. The lead was cast and 35 fathoms found. The captain and pilot consulted the chart, and making what they considered a proper allowance for tide and leeway, came to the conclusion that the land was Wicklow Head, bearing W.N.W., distant twenty-two miles.

The ship then stood on the same course till 3 P.M., when soundings were again taken and 25 fathoms found. Orders were then given to wear, but in wearing, and when nearly before the wind, the ship struck and remained fixed on the Kish Bank, about four miles S. of the Kish Lightship.

The point at which the ship so unexpectedly found herself was about twenty geographical miles to leeward of that at which the captain and pilot supposed themselves to be. In other words, the ship's actual course was about 28° or $2\frac{1}{2}$ points to the right of her supposed course. To what, then, was the error due?

In the first place, it seems impossible to attribute any large part of the error to an insufficient allowance for the effects of tide and leeway. It is true that from 7 to 1 o'clock a spring flood-tide, assisted by a southerly gale, had been running, but this was known to the captain and pilot. They had watched with great care throughout the day the courses, the leeway, and the rate, and, if we may judge from their estimate of the distance run, had estimated them with great exactness.

The next cause that suggests itself is a deviation of the compass not allowed for.

The steering-compass by which the ship was navigated was, we have seen, carefully adjusted in the Clyde, and was then nearly correct on a S.W. by W. course. Is it possible that any change in the magnetism of the ship had taken place, as has sometimes been found or supposed in new ships, which would account for the error? The answer to this must be in the negative. It is certain that any such change in the 'Glenorchy' would have had the effect of producing an error of the opposite kind, and, had it operated, she would have been found to the south, not to the north, of her supposed course.

Is there, then, any other cause adequate to produce an easterly deviation on a S.W. by W. course which might lurk concealed and undetected in the process of adjustment and only emerge during the voyage? To this the answer is emphatically Yes! *The Heeling Error.*

From the combined effects of the position of the steering-compass in the ship and of the ship in building, it is certain that there must have been a very large heeling error drawing the north point of the compass to the weather side of the ship. This error was probably not less than 3° or 4° for each degree of heel on a N. or S. course, before the chain-correctors were applied. The chain-correctors would reduce it about 50′, leaving 2° or 3° for each degree of heel. On a S.W. by W. course this error would be reduced to five-ninths of its maximum amount, or would be from 1° to $1\frac{1}{2}$° for each degree of heel. Hence if the 'Glenorchy' was heeling 10°, she would *certainly* have an easterly deviation of a point to a point and a half, or possibly more, introduced.

But it may be asked, if the ship had this large amount of heeling deviation, how did it escape detection in the earlier part of the voyage, when the ship was on a southerly course and the bearings of the lights were taken? and if detected, how was it not allowed for on the 1st of January?

The answer to these questions is remarkable; it is shortly this. The error *was* detected and *was* allowed for correctly when the ship was on the starboard tack. Afterwards, and when the ship was put on the port tack, it was still allowed for, *but in the same direction as before*, and therefore in the wrong direction. It was allowed for as a *westerly* deviation, although it had become an *easterly* deviation; and consequently the heeling error instead of being corrected, was doubled. And of this the cause was as follows.

Between Greenock and Lamlash, the ship being towed and on even keel, there were no means of detecting the error. Between Lamlash and the Calf of Man, when the ship was on the starboard tack and on a southerly course, an error of a *point of westerly deviation* was, as we have seen, detected and allowed for by the captain. This error I think there cannot be a doubt was heeling error.

But when on the morning of the 1st of January the ship tacked and was put on the port tack, the heeling deviation changed from being a westerly deviation to being an easterly deviation. The captain not being aware that there would be this change, and having no opportunity of verifying his course, continued to make the same allowance as before, and consequently made it, as I have said, in the wrong direction. As to the fact I think I cannot be mistaken.

The captain's words are:—"Our observations of the different lights all the way down Channel showed the compasses were inaccurate, and during the whole course on the starboard tack we had to steer one point more to the west than the proper course."

Then, speaking of the ship's supposed position at 1.30, he says:—"The courses I had observed, and the rate we were going, allowing for the tide and the leeway, *and the point the compass was in error while on the*

starboard tack, should have brought us to a point with Wicklow Head, lying W. by N., twenty-one miles distant."

It is clear from this that the captain made an allowance for the point of error he had discovered. Had he applied it in the opposite direction, he would undoubtedly have mentioned that he did so and why he did so.

The particular conclusions, then, which I draw from the facts of the case are these:—

1. There must have been a large heeling error affecting the steering-compass of the 'Glenorchy,' which, on the courses steered, would be a westerly deviation on the starboard tack, an easterly deviation on the port tack.

2. The westerly deviation detected on the starboard tack was this heeling error.

3. The true construction to be put on the captain's statement is, that when on the port tack he allowed for the point of deviation which he had detected on the starboard tack as a point of westerly deviation, not as a point of easterly deviation, as he would have done had he known the cause and the law of the deviation which he had detected.

4. That, in consequence, his supposed course was in error one point *plus* the heeling deviation, which, on a S.W. by W. course, was probably about one point more.

The general conclusions to be drawn from the history of the shipwreck seem to me to be:—

1. The great importance of selecting a position for the navigating-compass where the force of the ship's magnetism is moderate and uniform.

2. The importance of extending the usual process of "adjustment" of a compass to the ascertaining and (if necessary) the correcting of the heeling error. This is a matter of no difficulty if the compass-adjuster is duly instructed and supplied with the requisite instruments.

III. "Spectroscopic Observations of the Sun.—No. IV." By J. Norman Lockyer, F.R.A.S. Communicated by Dr. Sharpey, Sec.R.S. Received April 14, 1869.

I beg to lay before the Royal Society very briefly the results of observations made on the 11th instant in the neighbourhood of a fine spot, situated not very far from the sun's limb.

I. Under certain conditions the C and F lines may be observed *bright on the sun*, and in the spot-spectrum also, as in prominences or in the chromosphere.

II. Under certain conditions, although they are not observed as bright lines, the corresponding Fraunhofer lines are blotted out.

III. The accompanying changes of refrangibility of the lines in question